

# The TM6000 Crusoe: 1 GHz x86 System on a Chip

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Transmeta Corporation  
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# Talk Outline

## Crusoe Background

- TM5000 series

## Crusoe Roadmap

### TM6000 Crusoe: x86 System on a Chip

- Target Markets
- Features

### How Crusoe Compares in real systems (vs Intel)

- Power benchmarks
- Performance benchmarks

# Review of TM5000 Series

## Crusoe Processors

# Crusoe Technology

**Crusoe is the sum of**

**Code Morphing Software**

**+**



**=**

## Code Morphing Software

- ◆ Provides Compatibility
- ◆ Translates the 1's and 0's of x86 instructions to equivalent 1's and 0's for a simple VLIW processor
- ◆ Learns and improves with time

$\frac{3}{4}$

**+**

## VLIW Hardware

- ◆ 128-bit Very Long Instruction Word processor
- ◆ Simple and fast
- ◆ Fewer transistors

$\frac{1}{4}$

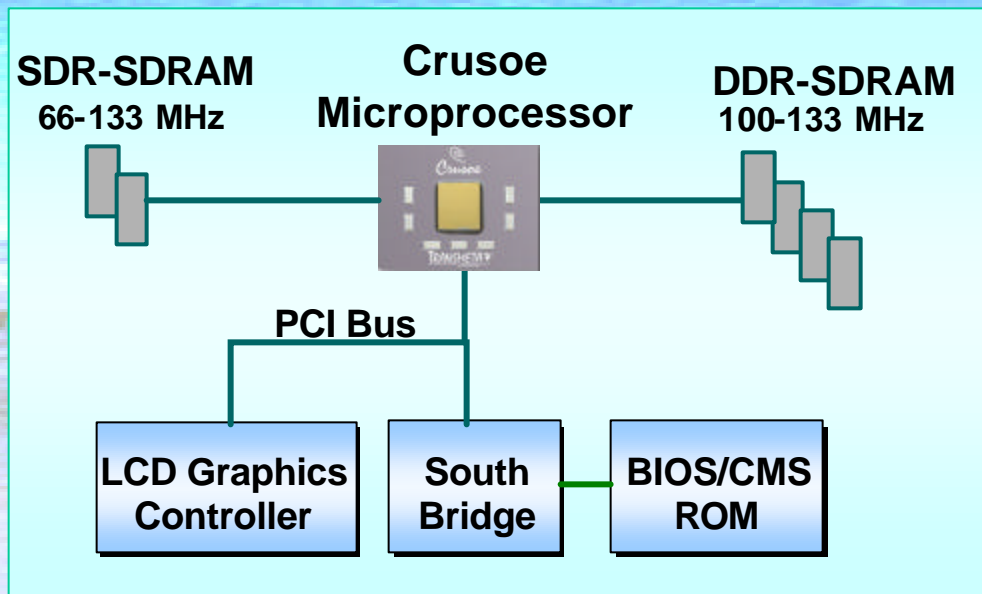
**Low  
Power**

**x86 PC  
Compatibility**

**PC  
Performance**

# TM5000 Crusoe began as a Highly Integrated Solution

## TM5000 Crusoe Includes:



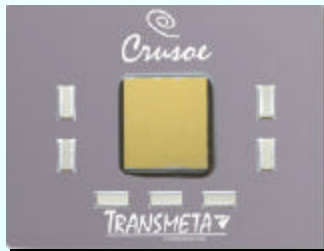
- 128-bit VLIW Processor
- PCI Bus Interface
- PC133 SDRAM Interface
- DDR266 DRAM Interface
  - Twice the speed
  - Lower power DRAM
- LongRun Power control

**Integration reduces two chips into one**

- PC Board space is a critical resource
- Further reduces power (no CPU bus)

# Crusoe Processor Introductions

**TM5400/TM5600**  
128-bit VLIW  
CMS 4.1



**500-667 MHz**  
512K L2 on TM5600  
256K L2 on TM5400  
0.18μ micron CMOS  
Volume Production: 2H 2000

**TM5500/TM5800**  
128-bit VLIW  
CMS 4.2



**667 - 800 MHz**  
800 MHz - 1 GHz 1H 2002  
512K L2 on TM5800  
256K L2 on TM5500  
0.13μ micron CMOS  
Volume Production: 2H 2001

**~Half the Power**  
**~Half the Price**

2000

2001

2002

# What's Next for Crusoe?

Two Distinct Customer Requests

**Performance**

**Traditional Notebook Markets**

- Increased performance is driving force



**New Markets -- Driven by:**

- Thermal Limits
- Smaller size and weight
- Lower Power/Longer battery life
- Lower Cost

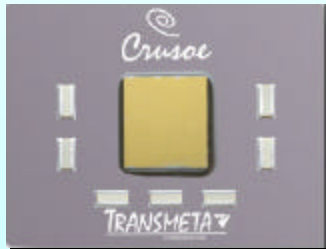
**6 – 10  
Hours**

**Battery Life**



# Crusoe Processor Roadmap

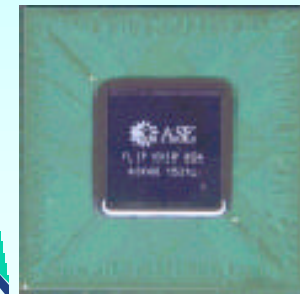
**TM5400 / TM5600**  
128-bit VLIW / CMS 4.1  
500 - 667 MHz



**TM5500 / TM5800**  
128-bit VLIW / CMS 4.2  
667 MHz - 1 GHz



**Next Generation Crusoe**  
256-bit VLIW / New CMS  
2-3x Performance



**TM6000**  
x86 System On a Chip  
128-bit VLIW / CMS 5.x  
1 GHz  
Less Power and Space



2000

2001

2002



# Previewing TM6000 Series

## x86 System on a Chip

# **TM6000 Target Market Segments**

- 1. New Smaller Form Factor Mobile PCs**
- 2. Ultra Dense Servers - Hundreds of CPU's per rack**
- 3. Convergence systems**
  - **Internet connected computing**
  - **Existing x86 embedded**
  - **Embedded RISC systems moving to x86**

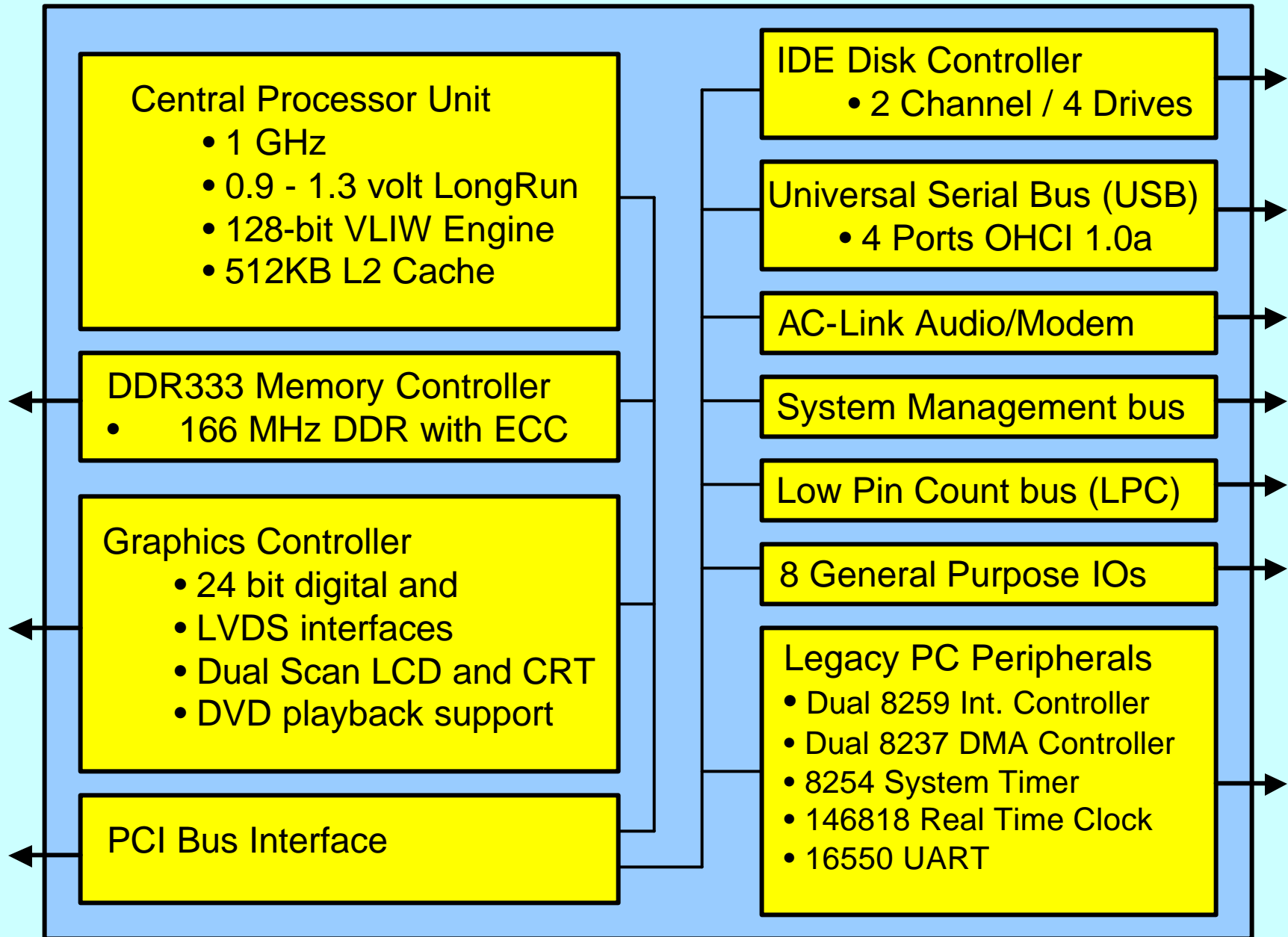
**All of these need**

- **Reduced printed circuit board space**
- **Low Power “Fanless CPU” operation**
- **Good x86 performance**
- **Low cost**

# **TM6000 Integrates multiple chips for Reduced Space, Cost and Power**

- **x86 PC Compatible CPU (TM5000)**
- **Integrated NorthBridge**
- **Integrated South Bridge**
- **Integrated Graphics**
- **Integrated Full System Power Management**

## Crusoe TM6000 Microprocessor -- x86 System on a Chip



# TM6000 Reduces Board Space Further

## TM5000 Solution

TM5800 CPU/Northbridge  
Southbridge  
Graphics Chip  
~10% bus routing overhead

## Package Size

25 x 32.5 mm = 812 mm<sup>2</sup>  
27 x 27 mm = 729 mm<sup>2</sup>  
27 x 27 mm = 729 mm<sup>2</sup>  

---

230 mm<sup>2</sup>

Total = 2,500 mm<sup>2</sup>

## TM6000 Solution

Integrated Chip  
• CPU  
• Northbridge  
• Southbridge  
• Graphics

## Package Size

28 x 28 mm = 784 mm<sup>2</sup>

Total savings of  $(2,500 / 784) = 3.2$  x less board space for these functions

# TM6000 System Level Power Management

## Transmeta LongRun technology:

- Scales Frequency and Voltage
- Hundreds of times per second
- Not dependent on the operating system

By integrating the TM6000, LongRun can now be applied to Graphics and Southbridge electronics as well.

## DVD Play Example:

### TM5800 Solution

CPU+NB = ~1.4 watts

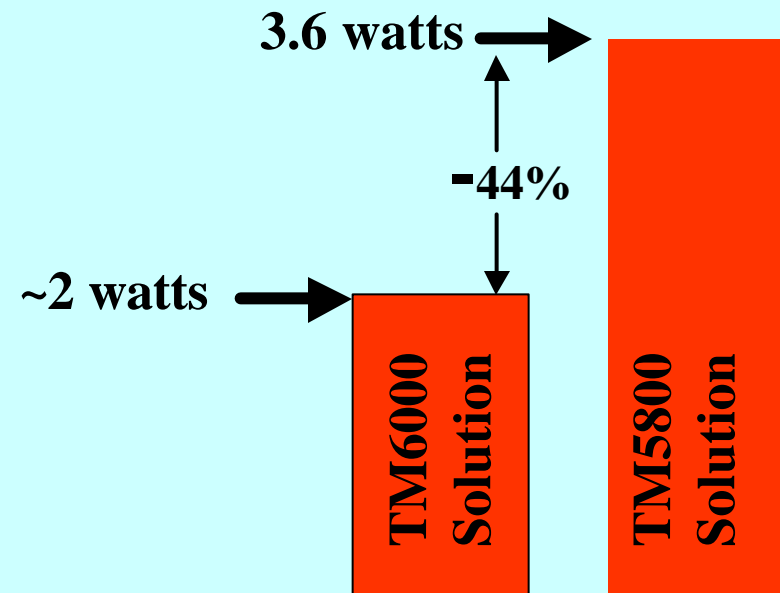
Southbridge = ~0.7 watts

Graphics = ~1.5 watts

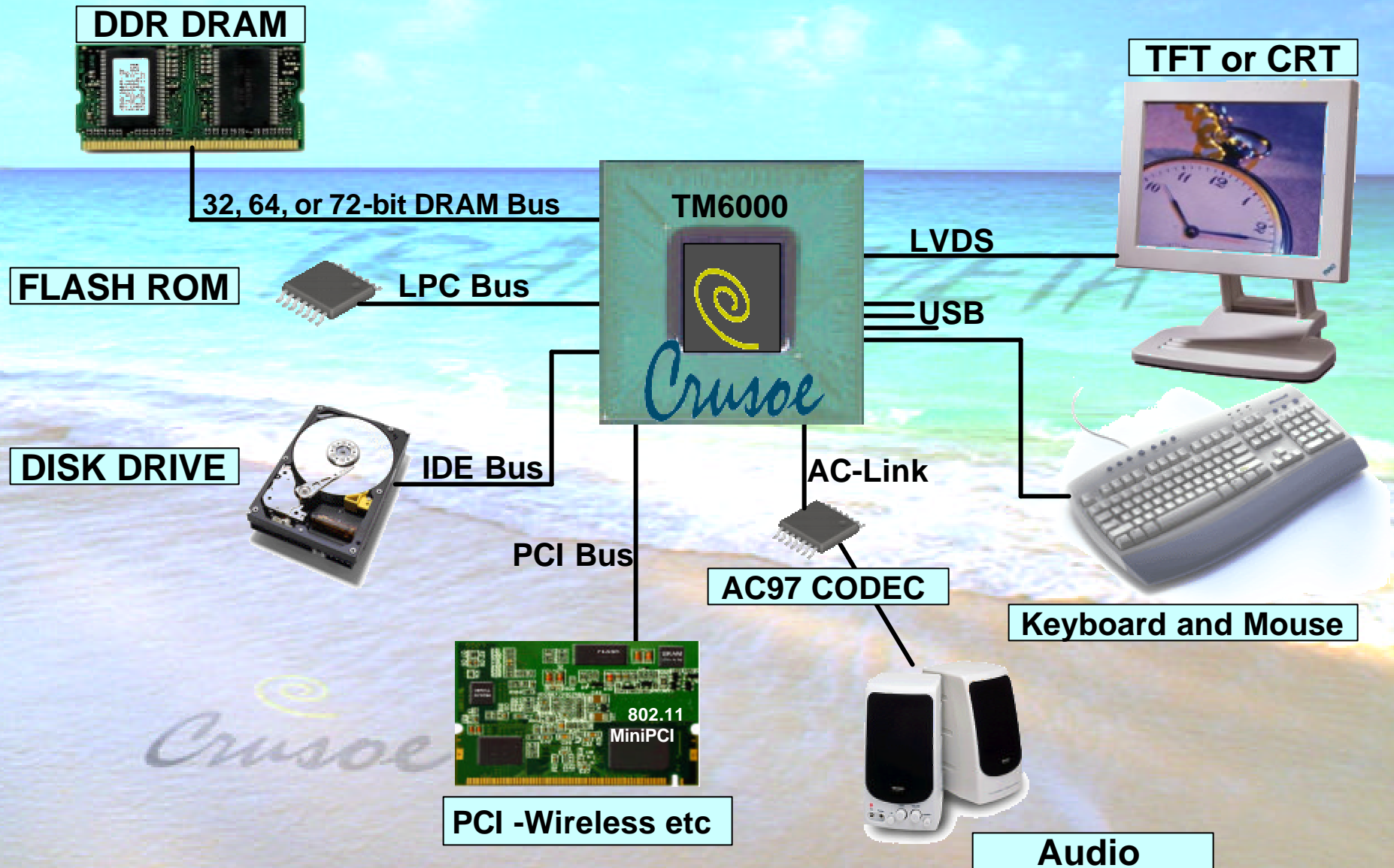
Total = ~3.6 watts

### TM6000 Solution

Total = ~2.0 watts



# System design is easy with Crusoe TM6000





# Embedded Convergence Devices

Many traditional RISC embedded platforms changing to x86 processors.

**Causes of the x86 migration:**

- Low cost embedded RISC processors no longer provide enough performance for video streaming and other Internet tasks.
- High performance RISC processors are far too expensive.

**x86 Platforms are far more economical**

- Can run the wealth of Microsoft and other PC software
- Can utilize commodity PC components
- More sophisticated power management
- Fan less operation often required
- Low cost of TM6000 System on Chip solution

**Examples:**

- DVD / Multimedia systems
- Internet and Telecom Routers
- Set-Top Boxes
- Print Servers



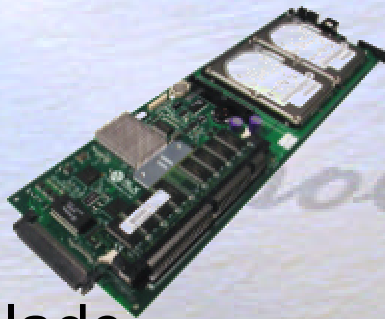
# TM6000 For Ultra Dense Servers

Dense Server Issues: Heat, Power, Space, Performance and Cost

New features in TM6000 for Servers:

- 72-bit SECDED ECC Memory
- Up to 2 GByte registered DIMMS
- Support for DDR 333 M-transfers/sec DRAM
- Two independent IDE disk channels for overlapped I/O
- Code Morphing Software Tuned for Servers
  - Optimization for server workloads
  - Enhanced DMA I/O system

TM6000 will enable the highest compute density servers



Blade



Blades in a Box

Rack



# **TM6000 Integrated Graphics**

## **For Ultra Dense Servers**

- **Graphics is just for Console - 2D is sufficient**

## **For New Form Factor PC's**

- **Cost, Size and Power are driving issues - 2D is sufficient**

## **For Embedded processing**

- **2D is sufficient**

## **For new class of Wireless Mobile Devices**

- **2D with multimedia/DVD support is primary**
- **3D with an external graphics chip is optional**

**Therefore, TM6000 supports 2D on-chip with 3D as external option**

- **Cost and power didn't yet justify integrated 3D for target markets**

# TM6000 Status

- **TM6000 processor is based on enhanced TM5000**
- **Designed for TSMC 0.13 micron CMOS**
- **Tapeout Q4 2001**
- **Engineering Samples 1H 2002**
- **Volume Production 2H 2002**
- **Aggressive pricing strategy**

# Benchmarks:

**An Apples to Apples Comparison**

**of Transmeta's Crusoe  
VS**

**Intel's Lowest Power x86 Processor**

# What and How to Compare

**Need to measure chips in real systems, not datasheets.**

**Intel has many different mobile chips**

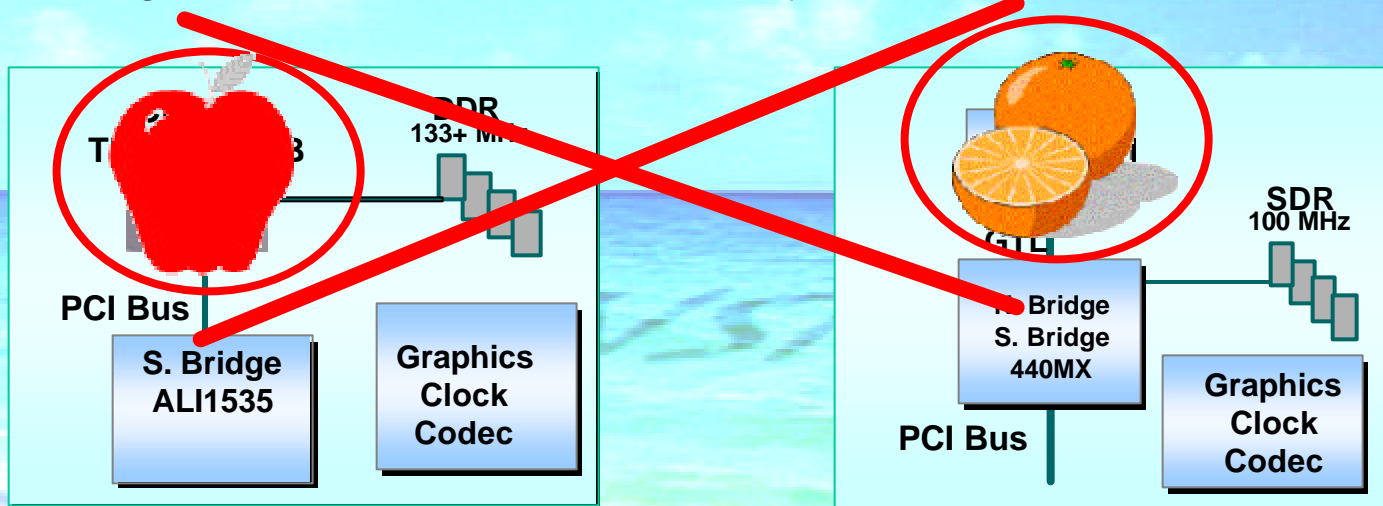
- **Pentium III ULV -- called the “1/2 watt” chip**
- **Pentium III LV -- called the “1 watt” chip**
- **Pentium III Processor M - called the “2 watt” chip**

**We made our measurements on the lowest power Pentium III we could actually find in a system in August 2001. This was the Pentium III ULV 600/300MHz with Speedstep.**

**We will compare this PIII ULV versus the TM5800 at 800 MHz.**

# Beware direct CPU to CPU comparisons

One might be tempted to compare only the power of the “CPU chip”



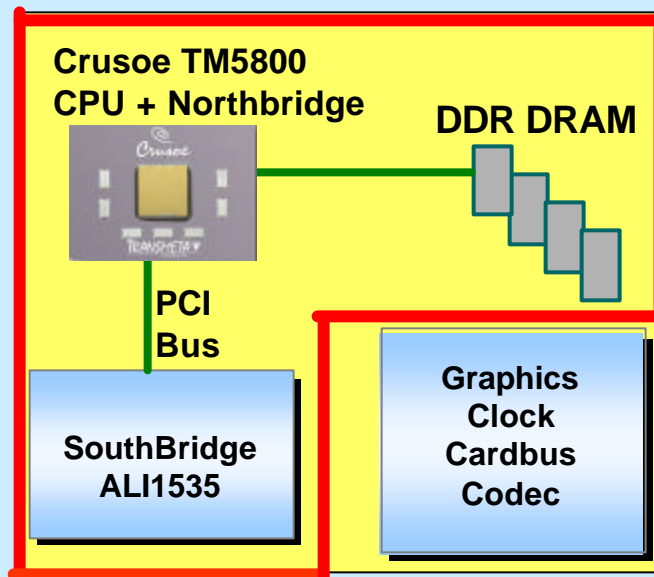
**Measuring CPU to CPU only is misleading:**

- Ignores Northbridge power
- Doesn't include all power in CPU to Northbridge bus
- Doesn't include differences due to DDR DRAM support
- Allows use of low duty cycle to mis-represent power savings



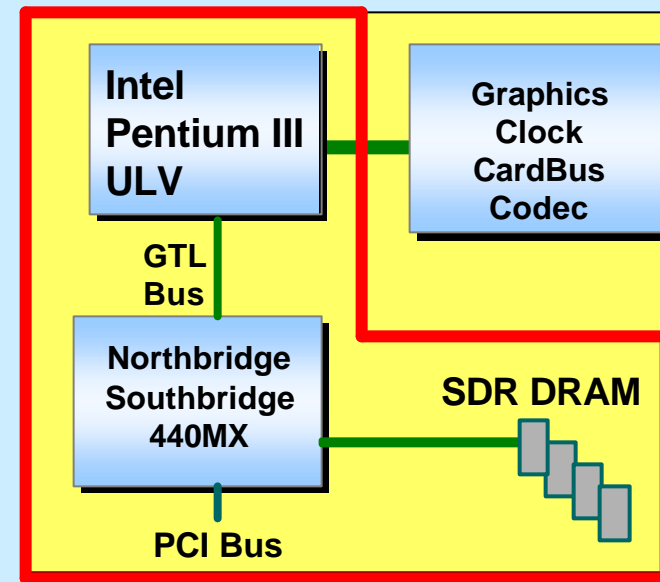
# Must compare CPU + Core Logic power

- CPU, Northbridge, Southbridge, Busses and Memory
- This allows a fair comparison that accounts for different system integration (NB, chipset) and capabilities (e.g. lower power DDR)



## Crusoe platform

- TM5800 CPU + Northbridge
- ALI1535 Southbridge
- DRAM Memory



## Intel platform

- Pentium III ULV CPU + GTL bus
- 440MX Northbridge and Southbridge
- DRAM Memory

# Power Measurement Details

## Crusoe measurement stations



**TM5800 Crusoe 800 MHz**

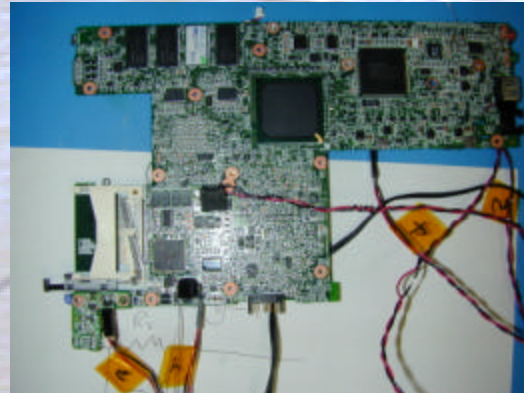
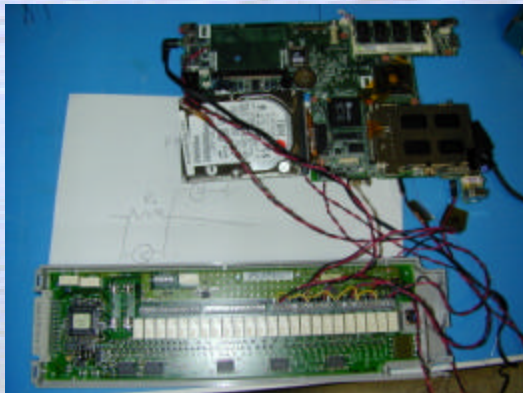
**vs.**

**Pentium III ULV 600 MHz AC/300 MHz DC**

**Added sense resistors to each power rail for data acquisition system to read power.**

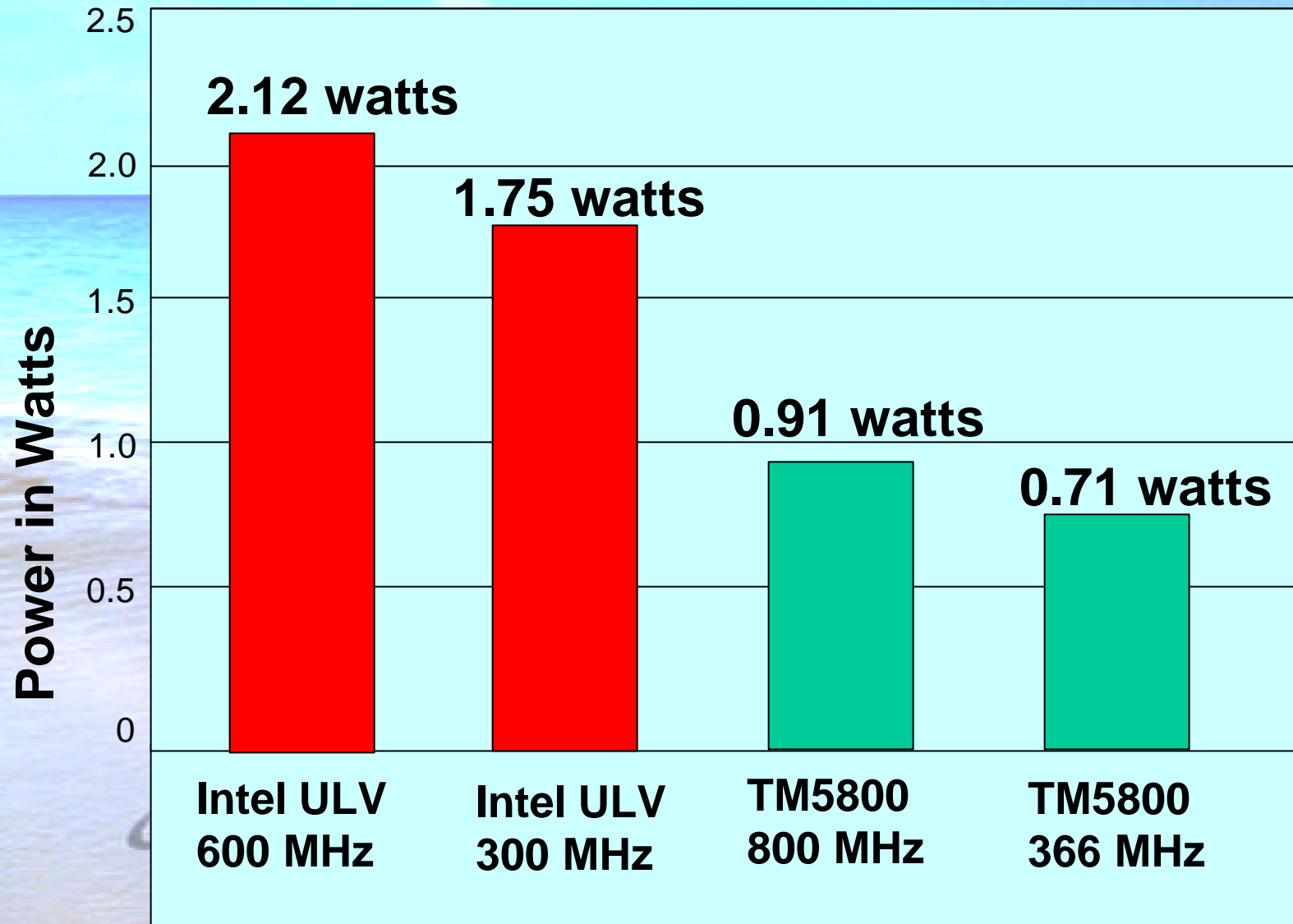
**Measured CPU Core voltages, 5 volt, 3.3 volt, 2.5 volt supply rails of measured components**

## Modified Intel Pentium III ULV motherboard

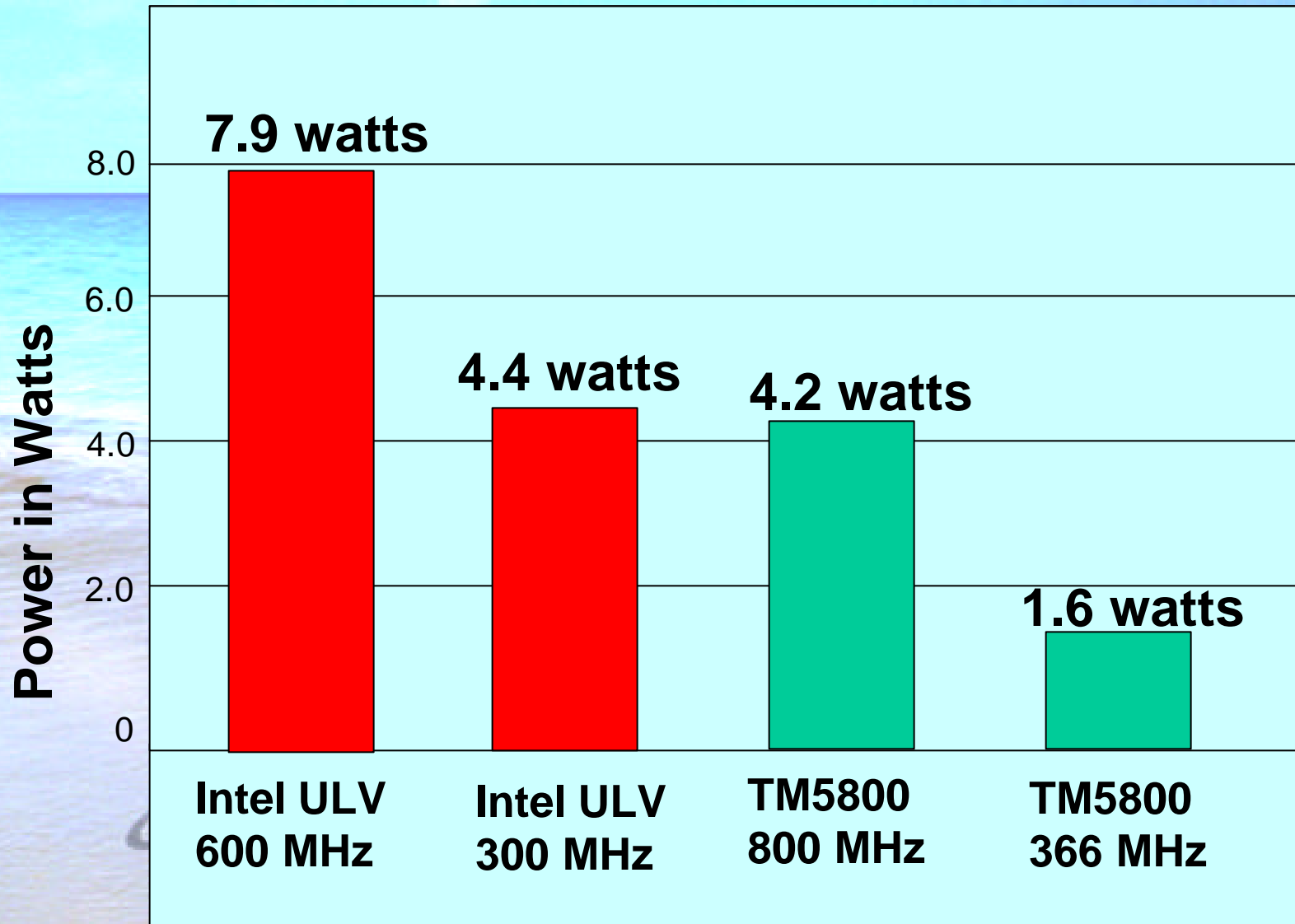


Note: Systems configured similar wherever possible. Both systems had 128MB DRAM, Windows 2000 SP2, IBM TravelStar 20GB DJSA-220 disk drives and 1024 x 768 graphics resolution on SMI 721 graphics.

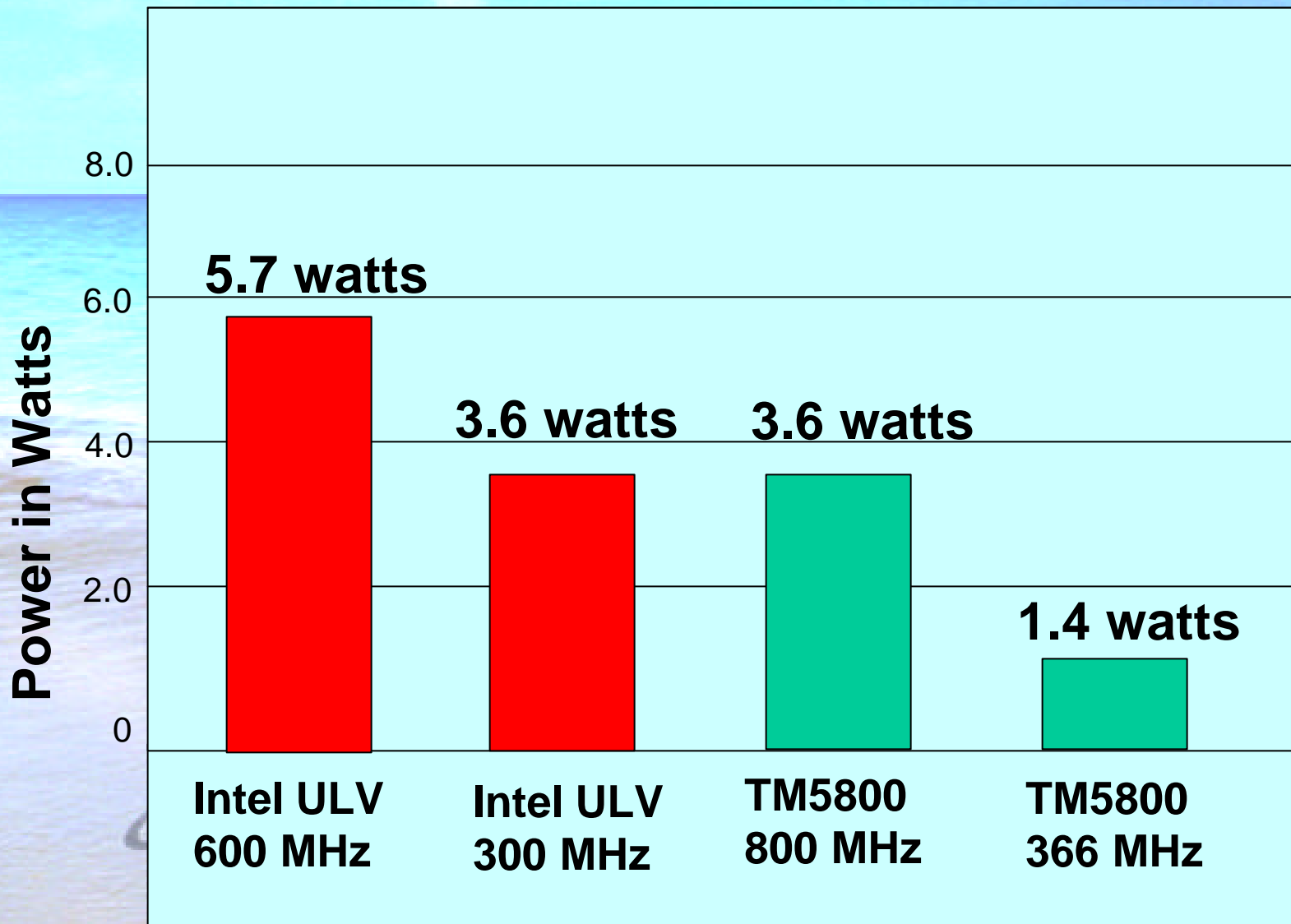
## Ziff-Davis BatteryMark 4.0.1 Comparison CPU + Core Logic Power



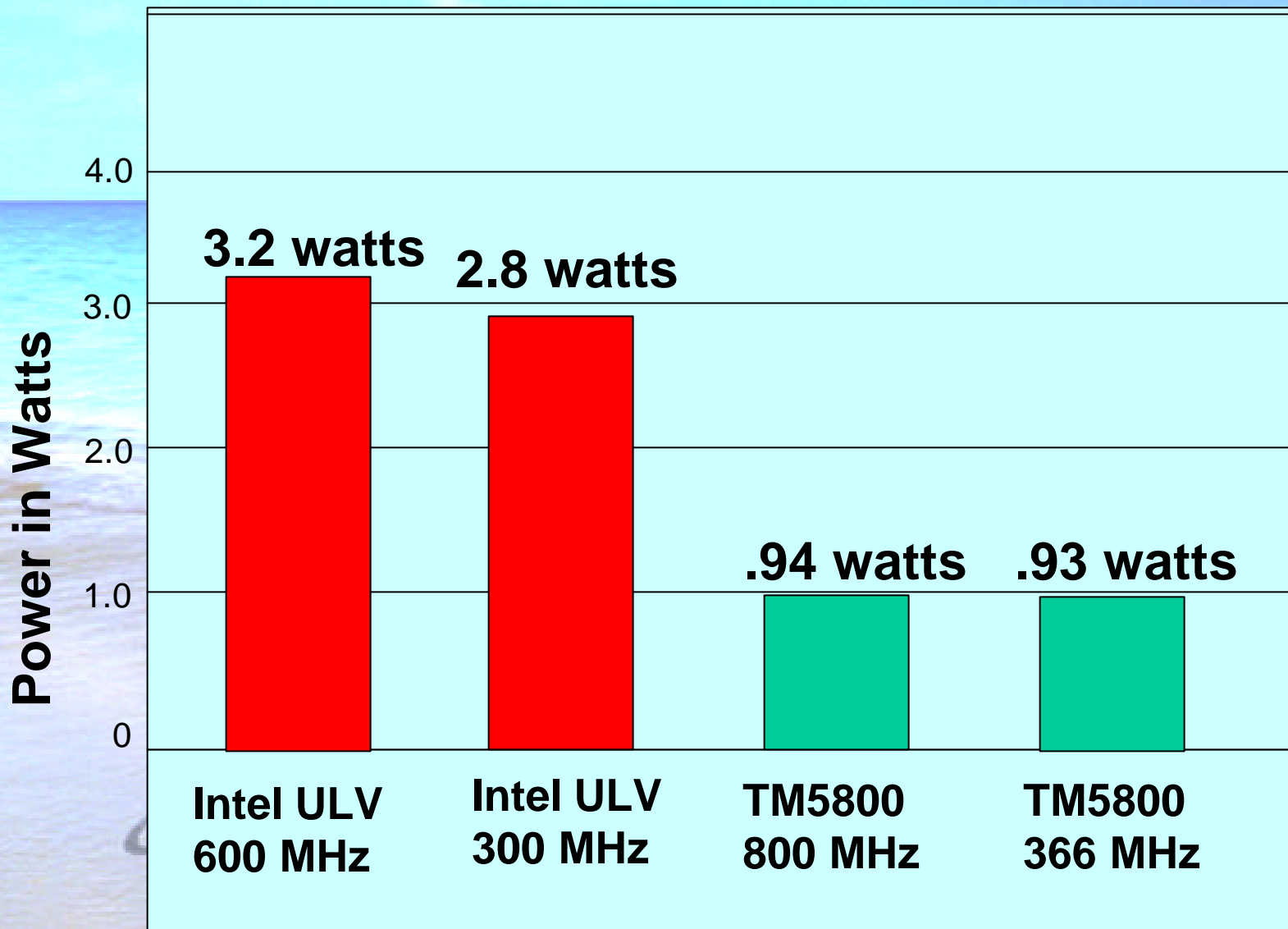
## CPUmark99 v1.1 Comparison CPU + Core Logic Power



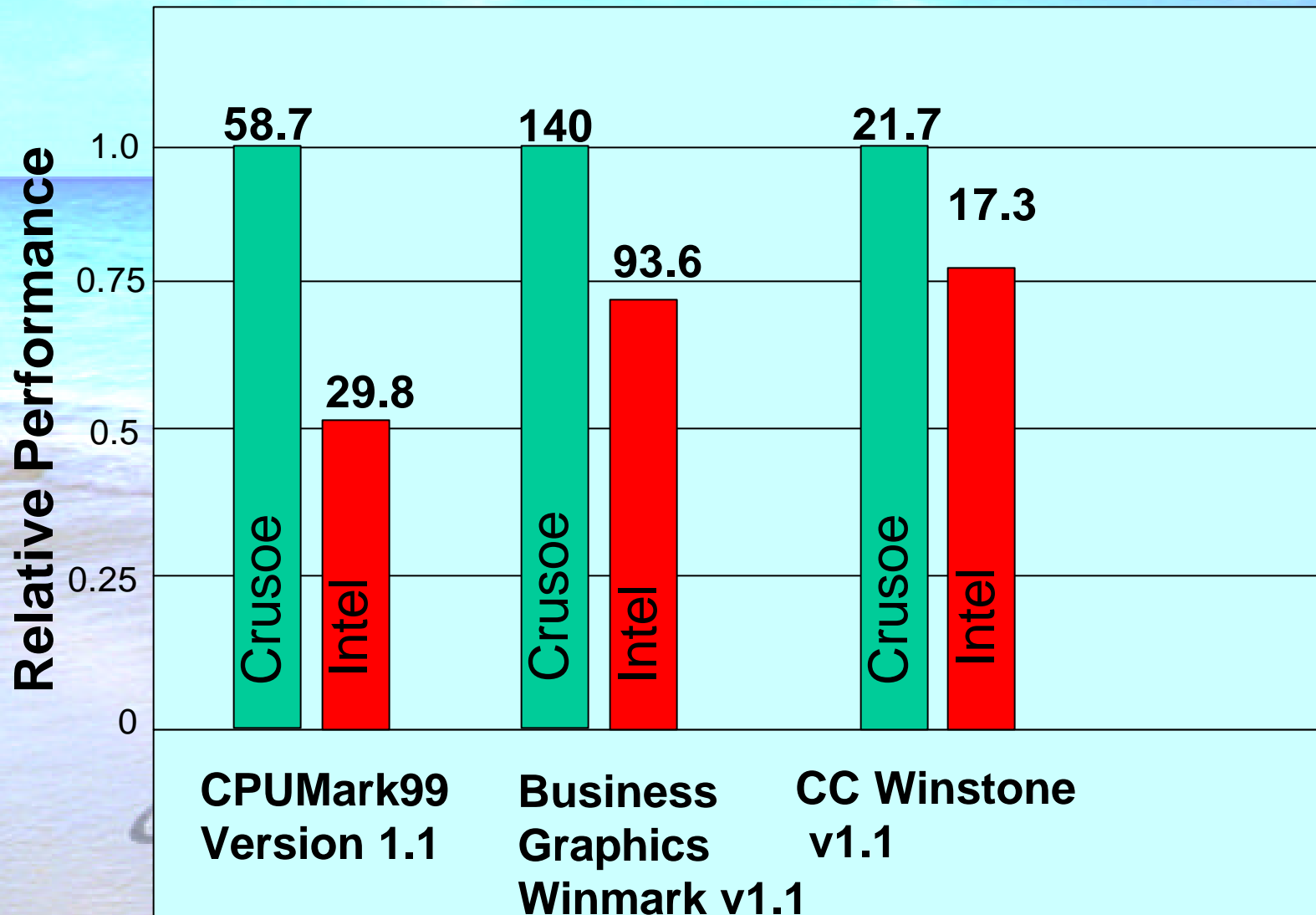
## Business Graphics Winmark v1.1 Comparison CPU + Core Logic Power



## MP3 Music Player Comparison CPU + Core Logic Power

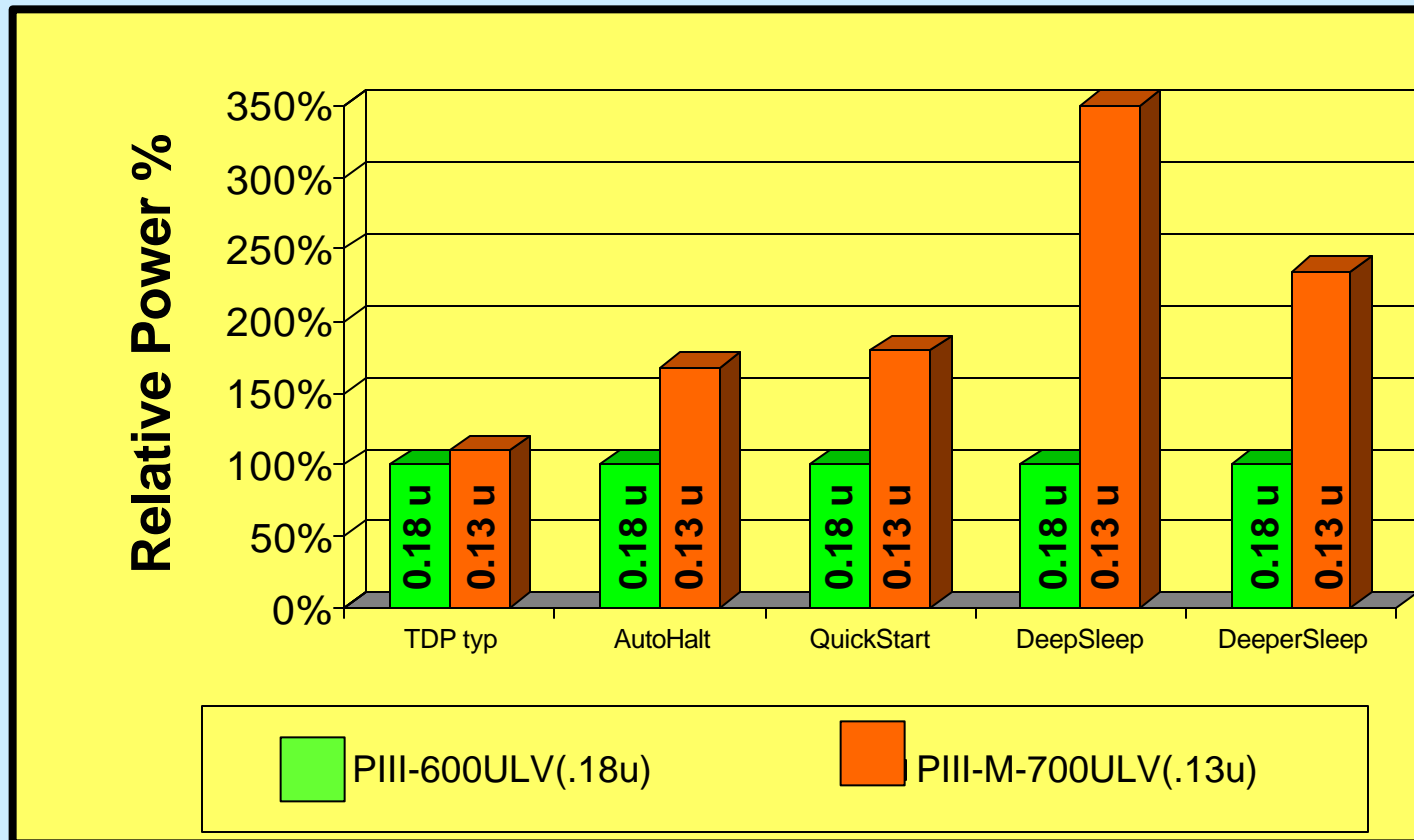


## Performance While Mobile (on Batteries) TM5800 vs Pentium III ULV





## How does the new 0.13 micron Pentium III Processor-M ULV compare to the 0.18 micron Pentium III ULV?



- ◆ According to the datasheets, the power is worse, probably due to leakage
- ◆ So Crusoe will be even more competitive against this new chip

Source: PIII-600 ULV Datasheet: [http://developer.intel.com/design/mobile/datashts/p3\\_ds.htm](http://developer.intel.com/design/mobile/datashts/p3_ds.htm), page 64  
PIII-M-700 ULV Datasheet: <http://developer.intel.com/design/mobile/datashts/298340.htm>, page 70

# Crusoe

- **Smaller**
- **Cooler**
- **Lower Power**

# Summary

**TM6000 is for New Computing Platforms where space, cost and thermal power are paramount.**

**Next Generation 256-bit Crusoe is for more traditional computing platforms wanting the highest performance with energy efficiency.**

**Measured data shows that Crusoe still holds the lead for lowest power x86 operation.**

The Crusoe logo is displayed in a stylized, cursive font. It is positioned on a light-colored, textured background that resembles a close-up of a microprocessor die.

# Acknowledgements

The TM6000 team built upon the work done by the TM5000 team that built upon the work of all the employees of Transmeta.

By building Crusoe processors, the employees of Transmeta have shown that software-based Microprocessors are practical and offer many advantages.

To all of them, thank you.

The Crusoe logo, featuring a stylized yellow swirl above the word "Crusoe" in a grey, cursive-like font.



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